Setting the Standard for Automation™

SCADA Standardization

Modernization of a Municipal Waterworks with SCADA Standardization: Past, Present, and Planning for the Future

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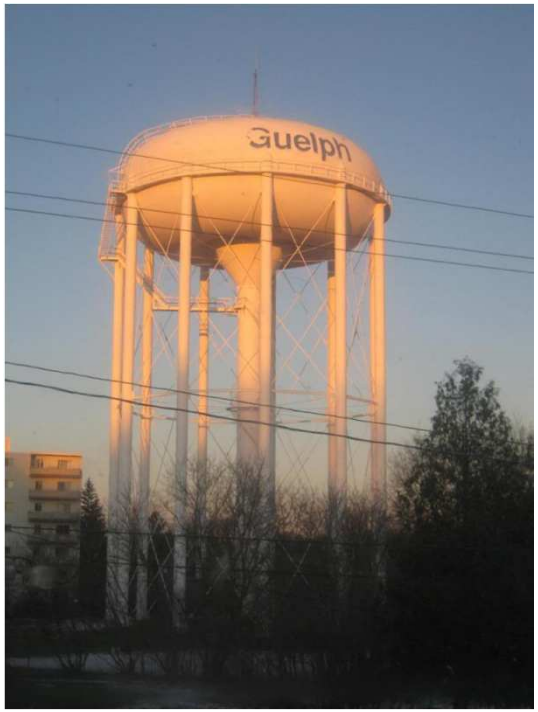
About Your Speakers

- Matthew Phillips, P.Eng.
  - Water Security Coordinator (SCADA) for the City of Guelph
  - Responsible for planning, construction, operation, maintenance of Guelph's waterworks SCADA system
  - Has been working with software/SCADA systems for past 10 years

- Graham Nasby, P.Eng., PMP
  - System Integrator with Eramosa Engineering
  - Background in various industry sectors including municipal water

Presentation Outline

- Introduction
- What do we mean by SCADA
- The Need for Standardization
- When to Standardize
- Steps required for a standardization program
- How to Write/Implement Standards
- Standardization Tips
- Case Studies
- Lessons Learned



City of Guelph

- Guelph is a city of 132,000 located in Ontario, Canada
- Located 45 minutes northwest of Toronto (across the lake from Rochester, NY, USA)
- Founded in 1827
- Situated at the confluence of the Speed and Eramosa Rivers
- Home to the University of Guelph and a major manufacturing centre

Guelph Waterworks

- Municipal waterworks began in 1878 with a “Holly System” for fire protection
- In 1880 the first artesian spring is discovered in city limits and used for drinking water
- More wells were added as the city grew

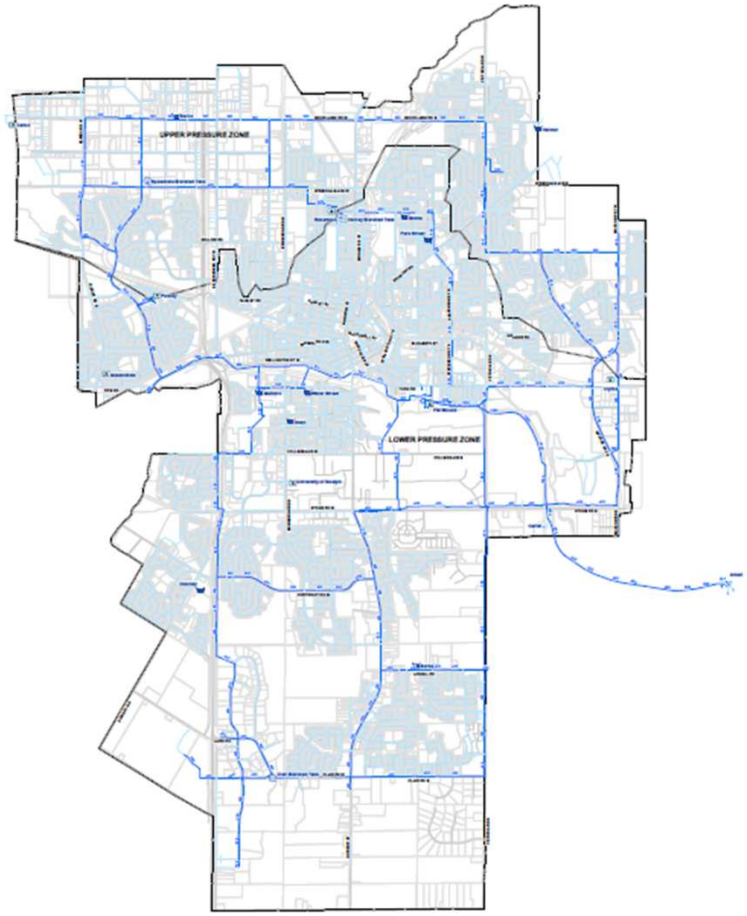
- In 1908 the Arkell Spring Grounds first used as a water source
- Arkell Springs were further expanded in 1963, 1970s and 2010
- 45-60% of city water comes from Arkell Springs
- Currently conducting a study shift more production to Arkell Springs

Guelph Waterworks System

- 6 active wells at Arkell Springs
- Glen Collector at Arkell Springs
- Arkell Springs water flows by gravity to city

- 13 active Urban Wells (with Reservoirs)
- 3 Water Towers
- 4 Booster Pumping Stations
- 2 pressure zones (high and low)

- Population of 132,000 as of 2010
- Residential and industrial customers
- 334 miles (534 km) of pipe, largest being 600mm
- 12-14 MGD (45,000+ m3/day) of delivered water



What do we mean by SCADA

- SCADA = Supervisory Control And Data Acquisition

- Includes:
  - PLCs that connect to equipment and sensors
  - OITs (for the PLCs) on local control panels
  - Automated control of equipment using PLC program logic
  - SCADA network which connects the PLCs and servers together
  - HMI screens on SCADA servers/computers (remote user interface)
  - SCADA servers that provide connectivity for HMI and data collection
  - Historian, Alarm Management System, Alarm paging, Report generation
  - All programming code that resides on PLCs, OITs, and HMI

- Does not include:
  - MCCs and motor starters
  - Back up electric relay logic

A Few More Definitions

- PLC = Programmable Logic Controller
  - Sometimes called a PAC, RTU, RPU, Controller, or Solver
  - Provides connection between SCADA network and raw equipment I/O
  - Contains the automatic control logic for equipment
  - Can be remotely controlled via SCADA

- HMI = Human Machine Interface (viewable on a SCADA terminal)
  - Resides on personal computers in the SCADA system
  - These are the “screens” that provide remote user interface for Operators

- OIT = Operator Interface Terminal (located on local Control Panel door)
  - Typically a proprietary industrial computer with a touch screen
  - Sometimes it is a full-featured PC-based computer with a touch screen
  - Often uses different programming environment than HMI

The Issue
& Why We Need Standardization

- SCADA continues to be a rapidly evolving field
- Cost vs. Functionality ratio continues to improve
- We can now do things that were cost prohibitive in the past

- Large projects are usually tendered, so it can be different integrator each time

- The tendency is to install the “latest and greatest” equipment each time
- When done over 10-20 years, the resulting systems can be very complex
- Complexity in SCADA is magnified because everything has to communicate

- Standards provide guidance throughout entire engineering design process
- Can significantly reduce design/review time
- Clear standards make construction contract administration easier

Hidden Costs of SCADA Complexity

- SCADA systems that are built over time can become very complex due to components having varying feature sets, connectivity, programming, and vendor support.

- Some of the many hidden costs of complexity
  - Harder to maintain & troubleshoot
  - Broader skill sets needed for operators, maintenance, engineers, programmers, etc.
  - More training to keep your staff up to date
  - More use of external consultants to cover skills not available in-house

  - Additional site visits by staff needed since equipment status reporting on SCADA varies
  - More possibility for mistakes since not all systems have same status detail over SCADA
  - Multiple vendor support contracts (one for each type of equipment/network)

  - Additional costs from extra time/effort needed to add new equipment to system
  - Ongoing difficulties trying to get incompatible equipment/networks to talk to each other
  - Signal converters, bridges, and protocol converters are often not as robust as native communications

The Decision to Standardize

- When to Standardize
  - You, and your organization, have enough experience with SCADA technology to understand what it can and cannot do
  - Know what you want
  - Know what you don't want
  - Understand the technical requirements of your region/facilities
  - Understand the needs of your user groups (operators, maintenance, engineering, etc.)
  - Understand the capabilities of vendors, integrators and in-house staff

- Resources Required
  - Must have the support of your management and procurement dept.
  - Need users who want to participate (operators, maintenance, engineering, etc.)
  - Need to have an overall long term Master Plan for your waterworks already
  - Be prepared to do some work before you see it pay off
  - Be patient as developing standards takes time and is an iterative process
  - Have a vision

DEVELOPING STANDARDS

"IF YOU DON'T SPEC IT, YOU DON'T GET IT"

Developing Standards

Steps towards Standardization

- Step #1: SCADA Master Plan

- Step #2: Decide what documents to use
- Step #3: Pick your SCADA Platform
- Step #4: Create the Documents/Templates

- Step #5: Test them out on Pilot Sites
- Step #6: Adopt as part of project workflow

- Step #7: Revisit/revise standards regularly

Step 1: Develop a Vision
SCADA Master Plan

- You need to have a long-term vision to standardize towards

- Before you can standardize, you need to create a SCADA Master Plan
- Look to your overall Waterworks Master Plan for ideas
- If you already have a SCADA Master Plan, when did you last update it?

- Do a survey of your current SCADA system
  - Is it fulfilling the needs of Operations, Maintenance, Engineering, etc.?
  - Are there features you wish you had?
  - Are there organizational goals that the SCADA system could help with?
  - Is your SCADA system easy to use or a pain?
  - Is the technology you are using becoming obsolete?
  - Are there any new or upcoming regulatory requirements?

- Where do you want to be in 5, 10, 15, 20 years?
- Write a plan on how to get there

Step 2: Decide How To Communicate
SELECT YOUR DOCUMENTS/TEMPLATES

- Standards are how you communicate and implement your SCADA Master Plan
- Documents to consider:
  1. Tagging Standard (Sites, Equipment, Electrical, SCADA points)
  2. SCADA Network Equipment and Addressing Standard
  3. Control Panel Specification (equipment, layout, wiring methods, etc.)
  4. Field wiring specifications / loop drawing standards
  5. List of Approved PLC Hardware
  6. PLC Programming Standard
  7. Standards for the OIT – Purpose, Hardware, Configuration and Programming
  8. Standardized SCADA software platform specification
  9. HMI Programming Standard
  10. Alarm Management Strategy/Standard (bonus points for using ISA-18.2)
  11. Data-Logging, Historian, and Data Redundancy Implementation Guide
  12. Other aspects of your workflow

Step 3: Select your Standardized Platform
HARDWARE, SOFTWARE & NETWORK

- The usual selection criteria for any automation solution applies...

- **but** you should also consider
  - Are you avoiding vendor lock-in? If not, is it worth it?
  - Standardization does not necessarily mean picking one vendor!
  - Pick the mix of equipment and software that best fits your needs

  - Will this equipment/software be still available 5, 10, 15, 20 years from now?
  - What is the vendor's roadmap for future product releases: is there continuity in connectivity, compatibility, and support?
  - Is there local vendor support available? Will it be available in the future?
  - What is the replacement plan when this equipment reaches end-of-life?

  - How does it affect your staffing and staff training plans?
  - Are there enough local system integrators with this skill set available?
  - Short term cost savings sometimes do not make sense in the long term

Step 4: Writing Standards
1. TAGGING STANDARD

- Use a universal tagging standard across your entire waterworks

- ISA-5.1 only provides basic guidance – you will have to write your own customized standard
- Use the same tagging system on everything to prevent confusion!
  - P&ID's, Equipment, Electrical Drawings, PLC hardware, PLC Internal Tags, SCADA tags, reports, etc.
- Must have a written procedure for adding new codes for new types of equipment

- Guelph uses a "five fragment" tagging system: aaa-bbbb-cc-d-ee
  - 1st Fragment "a": site code
  - 2nd Fragment "b": equipment code, with trailing numbers as needed
  - 3rd Fragment "c": device type, with trailing numbers as needed
  - 4th Fragment "d": signal direction (SCADA only)
  - 5th Fragment "e": signal type (SCADA only)
- Examples
  - A14BLG1TIQ01 = Arkell Well 14, Building 1, Temp Indication, Quantity In, 4-20mA Signal (Scaled)
  - AKWDTY5ALQLS = Arkell Well System, Well Duty 5, Auto Low Start (Level), Quantity In, Lo Setpoint

Guelph uses an Excel spreadsheet (8 printed pages) for their Tagging Standard

Step 4: Writing Standards
2. SCADA NETWORK STANDARD

- The SCADA network is the backbone of your system. Choose carefully!

- Things to consider:
  - Network technology to use
  - Connection medium: copper lines, fibre optic, and/or radio communication
  - Who owns/manages the communication medium
  - Failure modes when a network segment goes down
  - Can nodes be added/removed without having to take the network offline

- Guelph's network:
  - Ethernet so there is no vendor lock-in
  - Fibre optic network with redundant connections and auto-failover routing
  - Static IP addressing with small subnets for performance
  - Configuration of network routers/switches is done by their fibre optic network provider

Guelph has a 1 page preferred network equipment list
and an Excel spreadsheet of assigned/anticipated network addresses

Step 4: Writing Standards
3. Control Panel & Field Wiring Spec

- This is for the 120V control panels that your PLCs and OIT's go into
  - Let your electrical dept look after the 480/600V panels, Motor Starters and MCC standards
- Standardized panels make maintenance and troubleshooting easier

- Things to consider:
  - Size of panel, Internal layout, Wire colours, Pocket on inside of door for drawings
  - Provide CAD files as electrical design templates
  - Approved equipment list
  - Terminal blocks between PLC I/O cards and field connections (you would be surprised!)
  - Room for future expansion – unused space, terminals, ducts, etc.
  - Having a light with a door switch
  - Courtesy outlet for programming, even better put a programming jack on the front door
  - Standard pilot lights on every panel (power ok, fault, communications ok)
  - Standardized alarm beacon, horn, and/or horn silence button on every panel
  - Idea: Put a see-through window on front door so staff can see the I/O card status lights

Guelph includes this in their PLC Hardware Standard (3 pages of text, 4 electrical drawings)

Step 4: Writing Standards
4. PLC HARDWARE SPEC

- Decide on what you are going to call this thing!
  - PLC, PAC, RTU, RPU, Solver, Controller, etc.
- Have an approved list of hardware that is periodically updated

- Things to consider:
  - Specify a PLC platform/configuration for “small”, “large”, and “tiny” sites
  - Controllers, Controller firmware version
  - Standardized rack/chassis size, minimum size of power supplies
  - List of approved I/O Modules
  - List of approved Communications Modules
  - Card/module placement
  - Certain cards that you want installed in every PLC whether they are used or not
  - Remote I/O racks – hardware to be used and how they connect to the PLC
  - Remote I/O networks should be localized and separate from the main SCADA network

Guelph has a PLC Hardware Standard which covers this in 4 pages

Step 4: Writing Standards
5. PLC Programming Spec (1 of 2)

- This must consist of both a written specification and code template files

- Why the template files?
  - Programmers often don't like to read!
    - help them out and avoid disputes by providing template files for them to use
  - Modern PLCs and I/O cards have a myriad of settings – put them in the template file
  - Provide an "empty/base" template file along with several "finished example" template files
  - Make sure the template files will "compile" – don't provide broken programs!

- Why the written specification?
  - Makes contract administration much easier
  - Provides a "big picture" overview description
  - Includes detailed information about the programming approach you want used
  - Cover important aspects/nuances that you feel are important
  - Include explanations of why you want the code structured a certain way

more on the next slide...

Step 4: Writing Standards
5. PLC Programming Spec (2 of 2)

- In the written specification, some things to consider:
  - PLC controller firmware version and Programming Software version
  - Which IEC-61131 programming languages are permitted (Ladder Diagram, etc.)
  - Physical and Logical name of the PLC (in context of the Tagging Standard)
  - Code organization and naming: Tasks, Programs, Routines, Subroutines

  - Memory organization and naming (how it meshes with Tagging Standard)
  - Any standardized “abstract data types” or “add-on instructions” that are to be used
  - Guidance on special programming techniques specific to the PLC platform
  - Standard interfaces and functionality for the HMI/OIT to communicate with

  - Operating modes for SCADA-controlled devices: Local, SCADA-Manual, SCADA-Auto
  - How Raw Input/Output Registers from I/O cards to be mapped into main code
  - For PLC-to-PLC messaging, what message formats that are to be used
  - How alarms are to be generated on the PLC and how alarm bits are used

Guelph has a PLC Programming Standard (approx 30 pages)
and a set of sample template files for each type of PLC they use

Step 4: Writing Standards
6. OIT HARDWARE/SOFTWARE SPEC

- Define the purpose of the OIT
  - Viewing status/process data – everything or just critical points?
  - Provide a control interface? Limited control or full control? Data logging?
  - Do you really need an OIT if there is a computer with HMI screens on it nearby?
- Hardware
  - Dedicated hardware solution – often has its own programming environment
  - Industrial computer with touch screen – can sometimes use same code as the HMI
- Programming
  - Programming software name and version
  - Desired look/feel? Colours and symbols to use? Fonts? Icons? Navigation technique?
  - How are tags/communications in the OIT to be set up?
  - How is access security managed/controlled? Auto-logout after time delay?
  - Don't forget to provide code template files for the programmer !

Guelph uses OIT's to provide a view-only troubleshooting interface and secondary data logging. Due to the simplicity of the OIT, Guelph provides one standard template file to programmers.

Step 4: Writing Standards
7. SCADA SOFTWARE SPEC

- You need to specify exactly what software is being used on your SCADA servers
- Things to consider
  - HMI visualization (user interface) software
  - Tag Database that contains the “tags/points” the HMI uses
  - How the Tag Database gets data to/from the PLCs
  - Alarm Management Solution – including alarm annunciation, paging, and logging
  - Historian, and how the Historian collects data
  - Redundant Data Logging – do you need it? If so, how?
  - Make sure to specify version numbers and any patches/updates that are needed!
- Guelph uses
  - Integrated software package for HMI screens, alarming, and data collection
  - Specific I/O driver for PLC to Tag Database connectivity, redundant Tag Databases
  - Third party alarm paging software that interfaces with the Tag Database
  - Centralized Historian, with OITs at remote sites acting as redundant data collectors

Guelph covers this using 2 pages in their HMI Specification

Step 4: Writing Standards
8. HMI Programming Spec

- This must consist of both a written specification and code template files
- Refer back to the slide on the "PLC Programming Spec" for reasons why

- Designing effective HMIs is tricky!
- Use your HMI programming spec and template files to help the programmer
- Happy well-informed programmer = Good HMI's

- How to help the programmer:
  - Clearly define what the color "red" means
  - You can never have too many screenshots
  - Every screen element you expect them to use should be mentioned in the written spec
  - Clearly define how HMI security works and how users/permissions are managed
  - Provide programmer with "pre-built widgets" for as many things as possible
    - Layouts, Icons, Pop-up windows/faceplates, Scripting, Navigation methods, etc.
  - Provide a list of screens, pop-ups and elements that every new site must have
  - Template files must include a "fully working HMI application" out of the box

Guelph has an HMI Specification (approx 50 pages) with a large collection of template files

Step 4: Writing Standards
9. SCADA ALARMING SPEC

- Things to consider for alarming is a subject for an entire presentation by itself!
- You should provide
  - An “Alarm Philosophy” that details how you want alarming done
  - An “Implementation Guide” for the programming/configuration details for your platform
- How Guelph does alarming
  - All alarms are generated using logic on the PLCs
  - HMI receives alarm bits from the PLC via the Tag Database
  - HMI creates the alarm banners and provides the ack/reset/logging functions
  - 3rd party software is used to do alarm paging
  - Operators ack/reset alarms via the HMI, scripting sends the ack/reset bits to the PLCs
- How Guelph standardizes its alarming
  - Functional guidelines using PLC & HMI template files
  - Technical programming/configuration details in the HMI Specification
  - Currently looking into using ISA-18.2 to develop an Alarm Philosophy document

Step 4: Writing Standards
10. Data Collection, Logging, Reporting Spec

- Data collection, logging, and reporting are areas of growing importance
- Written specification/guidelines are needed for consistency

- Things to consider:
  - What to log – data points, alarm events, other events, notifications
  - Other items: HMI login/logout, setpoint changes, remote commands, security system
  - Do you log all analog/digital points, or just the critical ones?
  - How is the data going to be used? Which users need access to what?

  - Logging interval – time-based or change-on-value
  - Are there certain groups of points you wanted logged differently?
  - For each equipment type, is there a “default set” of data points you want logged?
  - If you use auto-generated reports, specify the formats – provide template files

  - How to set up and configure the historian

Guelph has 6 pages of Data Collection/Logging guidelines in their HMI Specification

IMPLEMENTATING STANDARDS

Guelph Waterworks
SCADA Standardization Timeline

- 2002 Discussions begin about developing a SCADA Master Plan
- **2003 Draft Standard Released**
  - Tagging, Control Panel Design, PLC Hardware, PLC Code Structure, Process Control Narrative Template
- **2003-2005 Draft Standard tested on pilot sites** → successful experience
- **2005 First Standard Released**
  - SCADA Master Plan, Tagging, Control Panel Design, PLC Hardware, PLC Code Structure, HMI Software Suite, HMI Screen Layouts, HMI colours and icons, HMI pop-up windows, HMI Scripting, Alarming Guidelines, Alarm Paging, Historian Specs, Redundant Data Logging Guidelines, Process Control Narrative Template
- **2005 Core network/server upgrades (Woods Pumping Station) to support standard**
  - Fiber optic networking infrastructure, new redundant SCADA servers
  - Upgrade program for SCADA network started
- **2005 Started using the SCADA standards as part of contract documents for all capital projects**
- 2005 Capital upgrades program for all SCADA equipment across city begins
- 2005-2009 Incremental updates to SCADA standard as needed
- **2009 Updated Standard released for PLC Programming (existing PLC platform)**
- **2009 Updated Standard released for PLC Programming (new PLC platform)**
- 2010 SCADA network upgrade complete, all sites now using fibre optic Ethernet network
- **2011-2012 Updated HMI Standard planned (once a major HMI server upgrade is completed)**
  - Standard to guide conversion of HMI screens and PLC communications to new HMI infrastructure
  - Developing a formal “Alarm Philosophy” (ISA-18.2) is currently being discussed

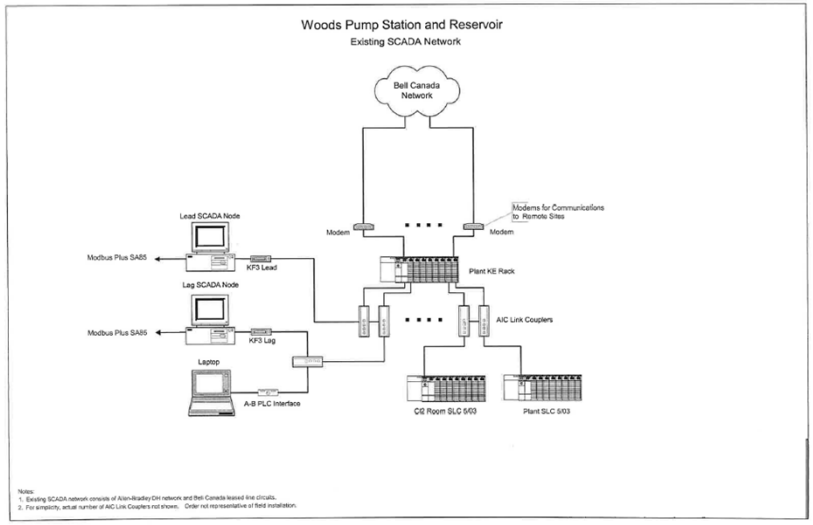
CASE STUDIES

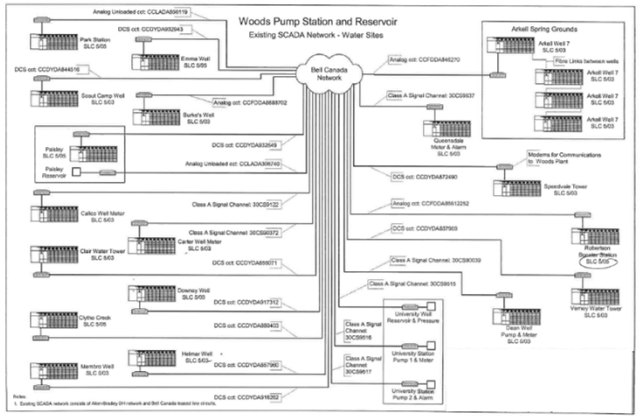
Case Study #1:
Core Infrastructure Upgrade (2005-2006)

- Install new core infrastructure to build the new standardized SCADA system on top of
- Background / Motivation
  - Existing servers varied in technology/functionality
  - Equipment was nearing end of life and becoming expensive
  - New servers/network needed to support 5 year upgrade program
- Project Summary
  - New Redundant SCADA Servers
  - New Centralized Historian with backup system
  - Central networking infrastructure converted to Ethernet
  - First segments of fibre optic network installed
  - Temporary bridging hardware to old network
  - Imported existing HMI screens "as is" onto new servers
  - Updating individual HMI screens to be done as separate projects
- Result: Infrastructure put in place for SCADA upgrades program

Case Study #1:
Core Infrastructure Upgrade (2005-2006)

BEFORE





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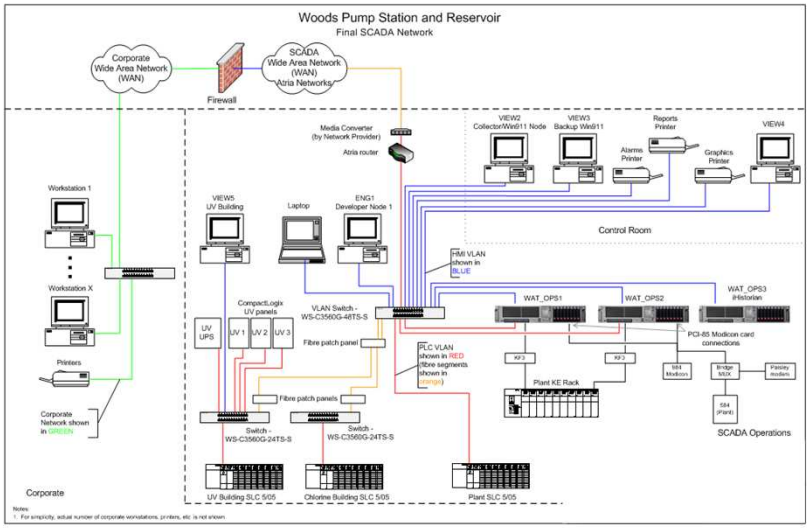
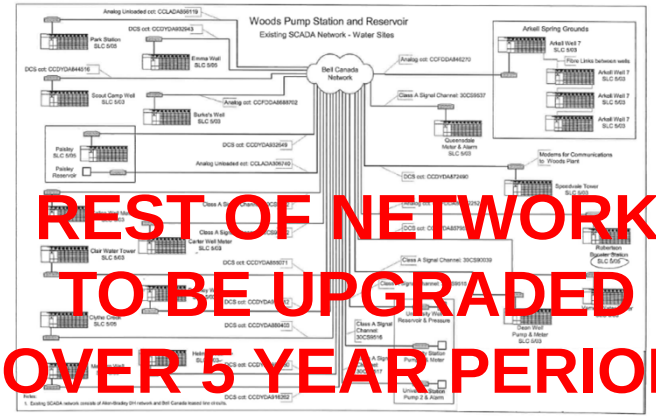


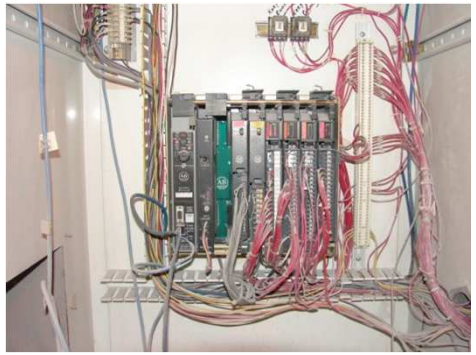


REST OF NETWORK TO BE UPGRADED OVER 5 YEAR PERIOD

Case Study #2:
Replacing old non-standard PLC's (2007-2009)

- Replace old non-standard PLC hardware that is incompatible with new network

- Background / Motivation
  - Some "performance specified" sites had older/exotic PLCs
  - PLCs that were obsolete and incompatible with new network
  - Two Pumping Stations to be converted



- Project Summary
  - One Station at a time
  - Phase 1: Install new control panel & PLC with unused I/O
  - Phase 2: Test new PLC programming in parallel
  - Phase 3: Cut-over I/O to the new PLC
  - Phase 4: Verification Period
  - Phase 5: Remove old equipment

- Result: Sites can now be maintained by in-house staff

Case Study #3:
Redundant Data Logging for Wells / MOE Request

- New regulatory requirement to have redundant datalogging for wells

- Background / Motivation
  - Communications outages were causing gaps in recorded data
  - SCADA Master plan was to transition to using redundant logging once new SCADA network was ready to support store/forward data logging
  - Regulator asked for redundant logging before network was ready

- Project Summary
  - Installed local OITs with that did store/forward logging
  - New network did not yet connect to these wells
  - Drove out with truck weekly to collect stored data
  - Connected OITs to new network when it was ready

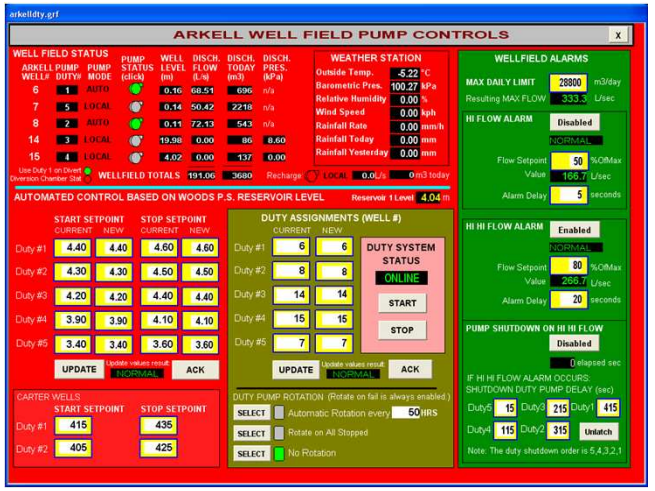
- Result: Master Plan helped city plan for and anticipate this

Case Study #4:
Arkell Springs Upgrade (2010-2011)

- Addition of two more wells to Arkell Springs
- Existing HMI and PLC programming did not conform to new standards

- Background / Motivation
  - 45-60% of city water comes from Arkell Springs
  - Wells could not be shut off during upgrade
  - Desire to operate as a well field instead of individual wells

- Project Summary
  - Phased approach to keep 2 wells running at all times
  - Phase 1: Bring fiber optic network to site
  - Phase 2: Bring 2 new wells online
  - Phase 3: Test new well field control with new wells
  - Phase 4: Upgrade 3 existing wells to new system



- Result: Improved uptime and easier operation/maintenance

Case Study #5:
New Build – Clair Rd. Pumping Station (2008-2010)

- New booster pumping station to accommodate south-end growth for next 20 years

- Background / Motivation
  - SCADA Master Plan called for eventual move to the “next gen” PLC
  - Opportunity test the new PLC platform from vendor

- Project Summary
  - Kept standards in mind as new PLC code was developed
  - Having documented strategy for old PLCs made new development easier
  - Savings in HMI development time (due to HMI standard)
  - Less time needed for FAT/SAT testing
  - Successful implementation

- Result: Knowledge gained was captured as a new standard
  - “PLC Programming Standard for platform X”
  - Adopted as part of the SCADA Standards package

TAKE AWAY POINTS

Standardization Lessons Learned

- Start by developing a SCADA Master Plan
- The SCADA Master plan will form the vision for your standardization program

- Developing the master plan and standards documents will require:
  - An initial time investment
  - Support from management and procurement departments
  - Active participation from users: Operators, Maintenance, Engineering, etc.

- Tailor the level of detail in your standards to the size and needs of your waterworks
- Regularly review/update your master plan and standards as “living documents”

- Once developed, use your standards for all capital projects – both upgrades and new builds

- Use your SCADA Master Plan to develop a prioritized and strategic timeline for upgrades

- **Make standardization work for you:**
  save design time, streamline integration, increase usability, boost reliability

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